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Comparison of tympanometric-peak pressure in morning versus afternoon kindergarten children in west-central Montana

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COMPARISON OF TYMPANOMETRIC-PEAK PRESSURE IN

MORNING VERSUS AFTERNOON KINDERGARTEN CHILDREN

IN WEST-CENTRAL MONTANA

by

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Tympanometry procedures to determine the status of middle-ear function are often a part of school hearing conservation programs in Montana. The obtained tympanometric-peak pressure is used to make decisions about audiologic follow-up and/or medical referral. The present study hypothesized that the time of day (morning versus afternoon) tympanometry was performed made a difference in the peak pressure obtained. Poorer-ear results of 1530 kindergarten children in west-central Montana were analyzed for differences related to morning versus afternoon testing. The tympanometry measures were presented in two forms: first, peak pressure in Pascals and second, peak pressure in discrete categories based on immittance screening pass/fail criteria.

The findings of the present study suggest that the time of day tympanometry is performed on kindergarten children (morning versus afternoon) makes a statistically significant difference in obtained results, with the mean peak pressure greater in the morning. However, the difference is clinically unimportant, as the same percentage of children in the morning and the afternoon would fail immittance because of their peak pressure. The cause may be related to the physiology of the eustachian tube, which is responsible for ventilation and pressure equalization in the middle-ear air space. Significant differences between each of the four months of testing also were discovered, consistent with previous research reporting seasonal variations in peak pressure. The area where the subject lived had a significant effect, possibly due to differences in the study sample from each area. In the area that included a significant native American population, atypical results were found in the relation of morning to afternoon mean peak pressure, possibly because of a reported racial difference in eustachian tube function. Sex and age differences did not cause significant differences in immittance results. Implications for further research were presented.

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CERTIFICATE OF APPROVAL

M.A., THESIS

This is to certify that the M.A. thesis of

Dale K. Smith

has been approved by the Board of Examiners for the thesis requirement for the degree of Master of Arts in the Department of Communication Sciences and Disorders

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CHAPTER I

INTRODUCTION

The use of acoustic immittance measures in determining the integrity of middle-ear function has become a routine, even essential, component of many school hearing conservation programs, particularly in the state of Montana. Of especial interest and importance is the immittance testing of kindergarten children. For many kindergarten-age children, the school hearing screening is still the first time a formal estimate of their hearing acuity and/or middle-ear function is made. Studies have suggested that the incidence of middle-ear disease in this group is quite high, perhaps higher than older school-age children (Brooks 1969, 1971, 1976, Johnson and Watrous 1978, Cummings *et al.*. 1977, Jordan 1972, Lamb and Dunckel 1976, Orchik and Herdman 1974, Cooper *et al.* 1975, Lewis *et al.* 1974). Many of these same studies have also shown the use of acoustic immittance measures to be helpful in the detection and subsequent referral for appropriate medical treatment and follow-up of middle-ear disease in all school-age children.

Purpose of the Study

In early studies using both the mechanical and electroacoustic impedance bridges, many researchers were most concerned with developing normative data on the actual impedance value, the quantity defined as z, for specific populations (Feldman 1963, 1964, 1967, Burke _et al._ 1970, Porter 1976). With the acceptance of the electroacoustic bridges and otoadmittance meters for widespread clinical use, interest has been refocused on the measurement of middle-ear pressure, generally represented by the tympanometric-peak pressure (or simply, peak pressure). This value is determined by the use of routine tympanometry procedures, which are for all essential purposes the same in both screening and diagnostic applications. The procedure typically involves the following steps: the sealing of the external auditory meatus (ear canal) with a flexible probe tip, the introduction of positive pressure into the ear canal, and the decrease of that pressure to the point at which the tympanic membrane is most compliant, generally as shown by a meter labelled "compliance". In theory, this is the point, or peak, at which the pressures on both sides of the tympanic membrane are equalized. Lamb and Dunckel (1976) have noted that "pressure measurements provide some of the more sensitive indices of middle-ear function with this group"(p. 179), when speaking of children. Lildholdt _et al._ (1980)reported that "tympanometry is an absolutely necessary tool in the clinical diagnosis of negative middle ear pressure" (p. 459). Schow _et al._ (1978) also found that what they termed the "degree of correspondence" between pressure readings by tympanometry and six factors of otoscopy was higher overall than the "degree of correspondence" between compliance values and the same six otoscopic factors. This is particularly important in school screening programs, where the tympanometric-peak pressure may be the only measurement recorded during the testing procedures, thus becoming much more important than the "compliance" value in clinical management. The guidelines for acoustic immittance screening recommended by the American Speech, Language, and Hearing Association (Committee on Audiometric Evaluation 1979) suggest that tympanometry be performed in conjunction with screening for presence or absence of middle-ear acoustic reflexes, but the tympanometric-peak pressure remains a prime decision-making factor in regard to referral and follow-up. In the flow chart given to illustrate these guidelines, the peak pressure consistently occupies the initial decision junction. In summary, peak pressure is an important factor in hearing screening programs when making decisions about referral and follow-up.

With the importance of tympanometric-peak pressure in school identification programs, the determination of the presence of variations from normative peak pressures is important in order that these variations may be considered when making clinical decisions of referral and follow-up. The purpose of this study, therefore, is to determine whether there is variation in the tympanometric-peak pressures of children who attend morning kindergarten sessions versus those of children who attend afternoon kindergarten sessions. Of interest are not only variations in the numerical value of the children's tympanometric-peak pressures, but in addition whether any variations discovered are large enough to affect the category in which the child is placed for the purpose of making clinical decisions regarding referral and follow-up. Since the data used in this study was from an established school hearing conservation program in west-central Montana, the results may have some potential to influence school hearing screening procedures for the age group of children that the study used as subjects, kindergarten children.

Rationale for the Study

In the vast majority of schools in Montana, the traditional morning-afternoon sessions of daily kindergarten continue, although in certain schools full-day alternating-day kindergartens are found. In the literature of education in general, and more specifically that of audiology, kindergarten children are typically studied as a single group, regardless of whether they attend morning or afternoon sessions. In the course of routine school hearing screening as part of a hearing conservation program in west-central Montana, informal observations suggested that there was a difference in the number of children who failed the hearing screening test in the morning kindergarten classes and the number who failed in the afternoon classes. In particular, there was a difference in the number who failed the screening solely on the basis of the acoustic immittance portion, notably because of the tympanometric-peak pressure criteria. To determine if the difference was significant to the degree that a full-scale study was warranted, a pilot study was undertaken which confirmed the informal observations to a certain extent. A description of the pilot study and the results is contained in Appendix A.

Overall, the pilot study did not offer unqualified support that there is a significant difference between the tympanometric-peak pressure of kindergarten children who attend in the morning and those who attend in the afternoon. The pilot study did, however, suggest that the small sample size from each school affected the outcome, and thus would indicate that analysis of the entire sample was justified to determine if a significant difference existed between the two testing times. Of course, other factors needed to be considered in the present study that were not addressed in the pilot study; especially those that might affect the the normative tympanometric-peak pressure of subjects as a whole.

Hypotheses

The primary intent of this study was to determine whether any difference between the tympanometric-peak pressure of morning versus afternoon kindergarten children can be shown. Stated specifically, the question was whether the time of day that immittance testing is performed (morning versus afternoon) can be expected to make a difference the obtained measurements of kindergarten-age children. The null hypothesis stated is: There is no difference between the tympanometric-peak pressure of morning versus afternoon kindergarten children. This hypothesis was tested in two ways. First, a determination of whether a significant difference exists based solely on the numerical values of each child's peak pressure in Pascals was made. Second, each child's peak pressure was categorized using discrete categories based on the criteria used in the hearing conservation program to make decisions regarding follow-up and referral. Then a comparison of the representation of each category from the morning versus afternoon kindergartens was made to establish whether equal proportions from each time existed in each peak pressure category. Analysis of the data in two ways distinguished between strictly numerical differences and those that may have clinical impact, as there would be if differences were found in the analysis of the categorized form of the tympanometric-peak pressure. This is true because the peak pressure categories were chosen as being those suggested by acoustic immittance screening pass/fail criteria, and are actually used to make clinical management decisions.

Definition of Variables

The variables were defined as follows: the dependent variable is the tympanometric-peak pressure/peak pressure obtained using routine tympanometry procedures. This pressure was expressed both as a numerical value in Pascals and as a member of a numbered discrete category of peak pressures. Independent variables of interest were defined as: 1) time of day the subject attended kindergarten when hearing screening was performed (morning versus afternoon) and thus time of day acoustic immittance measures were obtained; 2) sex of the subject; 3) age of the subject when tested; 4) month that the subject was tested; 5) general geographical area of the school the child attended at the time of acoustic immittance testing.

Review of the Literature

The need for an effective means of detecting middle-ear pathology in school hearing screening programs has been recognized since Darley (1961) defined these programs' collective intention to be

> to locate children who have even minimal hearing problems so that they can be referred for medical treatment of active ear conditions...[and] to identify not only children with a chronic disability but also children who have difficuly during only certain times of the year or under certain conditions(p. 16).

The classic study of Melnick et al. (1964) concluded that pure tone screening in the schools "did not adequately identify children with otoscopic evidence of active or past ear pathology" (p. 12). Acoustic immittance measures as an integral part of school screening have changed this situation, as Northern (1976) noted "...a 93% agreement between impedance screening and otoscopy..." as compared to "...only 61% between pure tone screening and otoscopy..."(p. 7). The need for acoustic immittance screening in schools is important in early detection of middle-ear problems, because as Harford (1978) pointed out

> the complications and sequelae of...middle ear disease present an important health, social, and educational problem that warrants the close attention of all professionals engaged in pediatric and hearing health care delivery systems (p. xi).

Eustachian Tube Function

In the Eagles (1972) report on the study of Pittsburgh school children, the importance of adequate eustachian tube function as regards hearing was recognized, and he reported "...by far the most common problem among otoscopically abnormal children was retraction and impaired mobility of the tympanic membrane which would sugggest impaired function of the eustachian tube" (p. 344). This problem arises because, as described by Lamb and Dunckel (1976), the eustachian tube is responsible for proper ventilation of the middle-ear space. If it does not perform adequately, the "air in the tympanic cavity will be absorbed by the blood vessels in the mucosal linings", causing negative pressure and associated retraction of the tympanic membrane. If proper ventilation is such a case is not restored "fluid drawn from the tissue linings will accumulate in the tympanic cavity" (p. 179). Eliachar et al. (1974) reiterated this relationship, saying "eustachian tube malfunction leads to a negative intratympanic pressure" (p. 174). One of the several ways the eustachian tube is opened to ventilate the middle-ear cavity is by the action of swallowing, which occurs at a "rate of one swallow per minute while awake, one swallow per five minutes while asleep, and one swallow every five seconds while chewing" (Seidentop 1977, p. 381). This is of particular interest to the present study, in terms of the effect time of day might have on tympanometric-peak pressure results. For example, the amount of negative pressure in the middle ear (and so the tympanometric-peak pressure) in the early morning hours might be affected by a reduced swallowing rate such as that while asleep.

As to the source of eustachian tube dysfunction, "the causes are many...[and] some are short-lived and recovery may occur without treatment, but others may never resolve without medical or surgical treatment" (Harker and VanWagoner 1974, p. 201). The educational implications of this problem become obvious for a child with even a minimal loss, for if "a child at school has a 20 dB [HTL] loss as his or her norm a dystubal function with a sustained negative middle ear pressure can create a significant additional hearing deficit" (Rock 1976, p. 14).

Incidence of Middle-ear Disease in the Kindergarten-age Population

The kindergarten-age population is particularly worthy of a study which investigates findings related to middle-ear problems. Eagles (Eagles et al. 1963) reported that "the least sensitive hearing levels occur in children aged five years" (pp. 89-90), the typical age for kindergarten children. Klein (1978) noted that, except for a high level of occurrence in infants less than two years old, "the incidence of otitis media declines with age, except for a limited reversal of the downward trend between five and six years of age, the time of entrance into school" (p. 13). Orchik and Herdman (1974) studied "preschool" children, aged 5 years, 5 months to 6 years, 7 months and found an approximately 50% immittance failure rate, indicating middle-ear problems in about half of the children in this age group. Cooper et al. (1975) in a study of 3251 school-age children (including 590 kindergarten children), "selected from a lower socio-economic population in which a high incidence of hearing impairment would be expected" (p.261), found 21% of the kindergarten children failing immittance testing. This was the highest failure rate of any grade level other than the special education population. In a longitudinal study of approximately five years' duration, Jordan (1962) found "the greatest annual increment of new cases of otitis media occurred at ages five through eight" (pp. 33-4). Brooks (1971), in one of his many studies of British school children, noted that the beginning year of school is a time for many middle-ear problems, saying "...a continuing study has been made of the incidence of middle-ear disorders in children from the time of their commencement of full time education at age 4 1/2-5 years (p. 337). He later reported that "studies of normal hearing children have shown middle-ear fluid occurs very frequently in the first year at school (age five in the United Kingdom)" (Brooks 1974, p. 141), and further, "as many as 30% of children in their first year at school may have middle ear effusions..." (Brooks 1976, p. 224). McCandless and Thomas (1974) also found that "most cases of negative pressure were found in the 3 to 5 year old age group" (p. 99), in a population that ranged from three to fifteen years old. Other studies have shown the same high incidence of medical referrals made for kindergarten children on the basis of immittance screening results, an incidence generally higher than all other regular grades, although no data is given about false-positive referrals (Cummings *et al.* 1977, Johnson and Watrous 1978, Roberts 1976). Once again, the importance of immittance screening was shown in a study by Harker and VanWagoner (1974) who stated that not only "the highest percentage of abnormalities [in immittance results] was seen in preschool and young school children", but also

> the preschool and early grades had the highest incidence of impedance screening failures and it was almost exclusively in these younger groups where some children passed audiometric screening but exhibited abnormal impedance measurements (p. 201).

These studies suggest the incidence of middle-ear disease to be high for kindergarten-age children, and that acoustic immittance screening is valuable in identifying these children.

Effects of Certain Variables On Tympanometric Results

Certain variables have been shown in previous research to have an effect on the tympanometric-peak pressure obtained, and those which have the most potential to influence this study will now be discussed. The apparently common problem of middle-ear disease continues into the first grade year of school; Beery *et al.* (1975) reported in a study a continued high rate of medical referral needed (14%) and an "at risk" rate of 29% of those first-graders tested. However, most research suggests that the incidence of middle-ear problems gradually decreases as age increases, beginning with an implied decrease from the Eagles *et al.* (1963) study cited earlier which found "hearing sensitivity increases with advancing age from this lowest point" (pp. 89-90) at five years of age. These findings are very probably related to the incidence of middle-ear disease. Barr *et al.* (1973) have defined this increase in hearing acuity more narrowly, saying "in the age groups from 4 to 16, the incidence of temporary conductive hearing impairment decreased with age..." (p. 426). According to Lamb and Dunckel (1978), "middle ear compliance, reflected in the amplitude of the tympanogram, shows little difference, regardless of age", but found a general decrease in the tympanometric-peak pressure of kindergarten through fifth grade children, and "this decrease...was accompanied by an overall decrease in air pressure variability among the older children...Similar trends have been reported by several investigators" (p. 179). Brooks (1969), in reporting on over 1000 children aged 4 years to 11 years, reported that

> the percentage [of middle-ear disorders] decreases with age; the first year at school shows the highest rate of middle ear disorders...the reduction in occurrence with age is probably attributable to a number of factors (p. 566).

Using the three most common components of hearing screening programs, pure tone audiometry, impedance screening, and otoscopy, Wilson and Walton (1978) found "increased performance with increased age is evident for all three tests" (p. 414). These studies all suggest that the incidence of middle-ear problems shows a gradual decrease as age increases, although no critical period of time for change is specified.

Again referring to the Pittsburgh study, Eagles _et al._ (1963) suggest no differences in acuity levels between sexes, although the same trend of acuity improvement with age is seen in both sexes. A national study conducted at approximately the same time, 1963-65, found "no significant differences between boys and girls" in terms of "hearing sensitivity" (Roberts 1972, p. 356). Barr _et al._ (1973), speaking of the epidemiology of temporary hearing loss, said "there was no sex difference" (p. 426). In his discussion of the epidemiology of otitis media, Klein (1978) reported that "in most studies the incidence of otitis media was not significantly different in boys from that of girls" (p. 13).

While a study by Brooks (1968) showed an equal proportion of boys-to-girls in both the normal and serous otitis media categories, he (Brooks 1969) later suggested although

> the spread of values for normals is independent of sex [and] boys and girls are equally likely to suffer from auditory tube obstruction,...girls are more likely to recover without the formation of fluid in the middle ear ... the occurrence of secretive otitis media is higher in boys than in girls (p. 567).

These findings were supported by the results of Hopkinson (1978) who further reported "as age increased, the preponderance of males represented in the larger negative pressure intervals was no longer evident" (p. 132). Lildholdt (1980) found that males suffer more frequently or for longer periods of time than do females from bilateral middle ear pathology" (p. 69). Fiellau-Nikolajsen and Lous (1979) noted that girls are "much more likely to recover without middle ear effusion" (p. 466), but also reported that "it was not possible...to demonstrate any significant sex difference in the distribution of tympanogram types" (Fiellau-Nikolajsen, p. 184, 1979). These studies point to the possibility of a sex difference in the incidence of middle ear disease, with males having a greater likelihood of having abnormal tympanometric-peak pressure over time, and thus more likely to have a problem significant enough to require medical referral and treatment.

Studies also have indicated that different times of the year may yield a different incidence of middle-ear problems. Eagles et al. (1963) discovered differences in hearing levels, noting a decrease in hearing sensitivity in "January, February, May and July", explaining that upper respiratory infections are more common in the winter months, and in the summer, "allergic manifestations are more common" (p. 94). These findings might be linked to the incidence of middle ear problems, particularly in light of the reasons Eagles et al. present for these changes in hearing acuity. Lildholdt (1980) has also defined certain "seasons" as being more likely to result in certain tympanometric-peak pressures and "when middle ear pressures are categorized and the incidence of each category is plotted by seasons of the year, middle ear pressure varies considerably according to season" (p. 68). Fiellau-Nikolajsen and Lous (1979) reported a greater incidence of high negative pressures in the winter months, most of which had spontaneously resolved without medical intervention by a summer follow-up testing. Most studies present data in terms of contrasting seasons and not for consecutive months.

Although not expressed in the same manner as the studies cited above, Brooks (1971) indicated that the time in the academic year will have an effect on the status of the middle ear, reporting

> A few weeks after the beginning of the first session (when school starts in the fall), there is a sharp rise in the number of children with fluid in the middle ear. This gradually subsides though there is a second peak in the spring (p. 337).

It may then be stated that the time of the year (at least by season) can be expected to affect the incidence of middle-ear problems and the measured tympanometric-peak pressure.

Hopkinson (1978) reports a difference between "white" and "non-white" tympanometric-peak pressures in regard to their representation in discrete categories of pressure. Other studies have also suggested that race may influence tympanometry results; of particular interest to this study are those dealing with the Native American population which suggest a higher incidence of middle-ear problems/immittance screening failures than in the white population (Lewis 1975, Roberts 1976, Johnson and Watrous 1978, Wiet _et al._ 1980, Beery _et al._ 1980). Bess (1978) includes native American children in a "high risk" population, which includes "certain populations of children [who] warrant special consideration for early detection of middle ear disease" (p. 292). The research suggests a higher incidence of middle-ear problems among the native American population.

Lildholdt et al. (1979) have recently reported a "lack of relationship between social groups and negative middle ear pressure" (measured by tympanometry). They termed this finding "surprising" although previous research is not comprehensive and assumptions are common. They suggest that the results may be due to "the general improvement of the basic living conditions in our society" (p. 214). Because this study was conducted in Denmark, its applicability to the present study is questionable.

Tympanometry is an objective procedure, making measurements obtained more reliable. No reports are found in the literature which suggest more than minimal cooperation is required from the person being tested (Paradise and Smith 1979). The literature neither examines or suggests that the subject's psycho-emotional state or intellectual level will affect the tympanometric-peak pressure measurements, if this minimal level of cooperation is obtained.

In summary, previous research has suggested that eustachian tube dysfunction and associated poor ventilation of the middle-ear space are responsible for many middle-ear problems in young children. Studies have also shown this problem to be common in the child's first year at school, typically kindergarten. As the child gets older, these middle-ear problems gradually become less frequent. While there is a slight tendency shown in published studies for males to have more persistent middle-ear problems, there does not appear to be a higher proportion of middle-ear problems in one or the other sex. The native American race is more likely to have middle-ear disease than the white race. There is no previous research regarding possible differences in tympanometric results between morning and afternoon kindergarten children.

CHAPTER II

METHODS

Subjects

The subjects included in the study were 1707 kindergarten pupils enrolled in schools in a five-county area of west-central Montana. Audiological services for these schools are provided by a special education cooperative. All of the children attended either a morning or afternoon kindergarten session; those who attended a a full-day alternating-day kindergarten at one school in the area were not included in the study. There were 1032 morning kindergarten children attending 52 classes and 675 children attending 36 afternoon classes for a total of 1707 pupils attending 88 different kindergarten classes at 44 different schools in the study area.

Further data that was gathered for each individual (other than tympanometric-peak pressure) was: 1) sex, male-female; there were 881 males and 826 females in the study (Table 1); 2) age in years and months at the time of immittance testing; the subjects ranged in age from 4 years, 10 months to 8 years, 3 months. Other information that was used in the study, such as time of day and month the child was tested and geographical area of the school that the child attended, was contained in the screening records for each subject along with the tympanometric-peak pressure measurement.

TABLE 1

Summary of Experimental Variables
by Time, Sex

	n		
TOTAL	1707		
BY TIME		% of total	
AM	1032	60	
PM	675	40	
BY SEX			AM n/PM n
MALE	881	52	547/ 334
FEMALE	826	48	485/ 341

Equipment

Each subject was tested using one of five commercially-available electroacoustic impedance bridges or otoadmittance meters used in the school hearing conservation program. The majority of the subjects were tested with one of the following instruments: Madsen model ZS 76, serial number 54320; Amplaid model 702, serial number 01605.Other instruments were used in obtaining tympanometry results, but to a lesser extent, and included the following: Madsen model ZS 75, serial number 52176; American Electromedics model 83 AR, serial number 2194/4194; Grason-Stadler model 1721, serial number 147. All of these instruments had been completely calibrated within one year of the study. Calibration checks were performed at approximately two-month intervals throughout the study. Daily listening and functioning checks were performed both before the morning and afternoon sessions of testing. The five instruments used in the study had a common pressure range of +2943 Pascals (+300 mm water) to -4905 Pascals (-500 mm water); that is, all instruments had <u>at least</u> this range of pressure variation available. Most had a greater range of pressures, either in the positive direction, the negative direction, or both.

Procedures

Tympanometry was administered to each subject as one component of the routine hearing screening for the school hearing conservation program. Tympanometry was preceded by otoscopic screening by the audiologist or other trained professional, e.g., the school nurse, and followed by middle-ear acoustic reflex screening. In general, the tympanometry was performed by one of two licensed audiologists with at least one year's experience in school hearing screening programs. Otherwise, the tympanometry was performed by a trained audiological assistant under the supervision of the audiologist. All five of the examiners involved in the actual immittance testing of the subjects used a procedure similar in nature both in terms of technique and interpretation. An inter-examiner reliability study across subjects using six adult ears resulted in all measurements on any one ear being within +/-196 Pascals of all others, and further analysis revealed Pearson product-moment correlation factors ranging from .91 to 1.00, considered adequate for the purposes of this study (Appendix B).

Routine acoustic immittance procedures were followed to obtain the tympanometric-peak pressure, i.e., the pressure reading at which the "compliance" or "cm3" meter showed the maximum excursion from the starting point with positive pressure in the ear canal (the "peak"). Measures were obtained from each subject in a similar manner, one ear at a time. Initially, +1962 Pascals of air pressure was introduced into the external auditory meatus so that a satisfactory seal was assured, then the pressure was decreased until the point at which the "peak" was reached. The pressure reading at that point was recorded. If no peak in the needle excursion was observed at the maximum pressure of the instrument, "NPP" for "no peak pressure" or "max" was recorded.

In general, the morning kindergarten children were tested first of all the children at the school, and the afternoon kindergarten children were tested immediately after the lunch break. Therefore, at least one hour separated the immittance testing of the morning kindergarten and the testing of the afternoon kindergarten, although in most cases more time elapsed between the morning and afternoon immittance testing. For example, if there was only one kindergarten class at each time at a school, up to three hours separated the two classes′ immittance testing times.

Criteria for Inclusion in the Study

Certain criteria were established before a child was included this study. First, tympanometric measurements were required to be obtained from both ears of the subjects. For example, subjects who could not be tested or could only be tested in one ear were not included in the study sample. Those subjects who failed otoscopic screening because of observed ventilation tubes in one or both tympanic membranes, possible foreign object in the ear canal(s), cerumen blockage, or other otoscopic observations that might affect tympanometric results were not included. Those subjects with no peak pressure and a greater-than-normal equivalent ear canal volume (cl), implying either a ventilation tube in the tympanic membrane (perhaps not observed) or a perforation of the tympanic membrane were not included in the study sample either. Those subjects not tested on the same day(s) as the rest of the subjects in the same school, because of being absent or unavailable for the initial screening, were likewise not included. Two additional criteria were imposed regarding the age of the subjects. The first was that the subject's birthday was required to be known for their inclusion in the study. If the birthday was not able to be collected from the school, typically because the subject had moved since the testing, they were excluded from the study sample. Secondly, only those subjects who had reached their fifth birthday and had not reached their seventh birthday when the immittance measures were obtained were included.

Utilizing all of the criteria outlined above, 177 subjects were eliminated from the study sample (Table 2), leaving a total sample of 1530 subjects to be included in the data analysis. This means approximately 10% of the subjects in the study area did not meet the established criteria for inclusion in the study. The two main reasons for exclusion were being absent/unavailable for testing and no birthdate being available to determine age. These 177 children were made up of 104 morning and 83 afternoon kindergarten children, leaving a study total of 928 children from the morning and 602 from the afternoon kindergartens. The 177 subjects not meeting the criteria further broke down to 87 males and 90 females. The final study sample thus included a total of 794 males and 736 females.

TABLE 2

Summary of Subjects Excluded

	n	
TOTAL	177	% of sample n(1707)=10%
BY TIME		
AM	104	
PM	83	
BY SEX		
MALE	87	
FEMALE	90	

REASON FOR EXCLUSION	n	% of 177
absent/unavailable for testing on screening day	101	57
no birthdate available/age unknown	44	25
ventilation tubes present/large cl(ear canal vol)	14	8
fail otoscopic (other than tubes)	2	1
could not test	7	4
younger than age range limit	3	2
older than age range limit	6	3

Definition of Tympanometric Results

For the purposes of this study, it was decided to use only one number to represent each subject's two obtained tympanometric- peak pressures, rather than treating each as a separate and independent pressure as was done in the pilot study. This was no problem if the subject's two peak pressures were equal between ears. If, however, the two were not equal, the poorer (i.e., the farther of the two pressure points from 0 Pascals) was used. This decision was made as the poorer pressure is more representative of and more interesting to the overall study. The "real-world" nature of the study made it desirable to use the poorer-ear score and determine if a category-based difference existed, implying a clinically important difference existed as well as a difference based only on numerical values. In the hearing conservation program, if one ear is poorer than the other, clinical decisions are most often based on poorer-ear results. Medical referrals are made on the basis of the poorer-ear immittance. A normal tympanometric peak in one ear has very little meaning in terms of clinical management and disposition in light of an opposite-ear peak which is indicative of middle-ear disease and calls for a medical referral. Differences between the ears in one subject may not be statistically different, but in terms of management, as little as 100 to 200 Pascals difference between two ears may change the referral or follow-up procedures completely. Generally, an audiologist's attention and interest is focused on poorer-ear tympanometric-peak pressure, making it the basis for clinical judgments and decisions.

Another aspect needing definition was the assignment of a number for analysis purposes to those subjects whose poorer tympanometric-peak pressure was recorded as "no peak pressure" or "max". Since the common range of the instruments used had a lower limit, as noted earlier, of -4905 Pascals, this value was assigned to those subjects with a poorer-ear result of "NPP". A lower tympanometric-peak pressure than -4905 Pa would be recorded only very occasionally, and in the data for this sample, the lowest peak pressure recorded other than "no peak pressure" was -4414 Pa. The assigned pressure of -4905 Pa also helped to assure that the analysis of results was not overly influenced by a concentration of "no peak pressure" results in one area as perhaps might be the case with a larger negative value, for example, -5886 Pascals. However, the selected value was considered to be an excellent numerical representation of the typical, practical lower limit of pressure used in actual tympanometry and so more closely approximate the actual limit of pressure used to define those results recorded as "no peak pressure".

Analysis of the Data

The data was arranged for each subject in the sample in the same manner. This was done in order to carry out computer-assisted statistical analysis.

The measurement variable, tympanometric-peak pressure results were presented in two forms: a) numerically expressed peak pressure, in Pascals, of the poorer-ear, between +1962 and -4905; b) peak pressure category, based on the acoustic immittance screening pass-fail criteria established by the American Speech, Language, and Hearing Association (Committee on Audiometric Evaluation 1979). The five categories as defined for this study are 1) normal: +490 to -490 Pa; 2) mild : +500 to +981 Pa, or -500 to -1962 Pa; 3) moderate : greater than +991

Pa or -1972 to -2943 Pa; 4) severe negative: greater than -2953 Pa; 5) flat: no pressure peak at maximum pressure. The fifth category was added to better assess the effect this type of results had on the study as a whole, and also in an attempt to show how the "no peak pressure" results affected the numerically-based analysis. These two methods of presenting the peak pressure for analysis were used because of the stated desire to distinguish between a statistical difference that was numerically-based and a difference that was category-based, in order to derive clinical significance from the study.

Information about individual subjects specified by the five dependent variables was: a) time of day the child attended kindergarten when tested and therefore the time of day tympanometric-peak pressure was obtained-- 1) morning, or 2) afternoon; b) sex of the child--1) male, or 2) female; c) age of the child in an age category represented by a single integer-- 1) 5 years, 0 months up to (but not including) 5 years, 6 months, 2) 5 years, 6 months up to 6 years, 0 months, 6 years, 0 months up to 6 years, 6 months, 4) 6 years, 6 months up to 7 years, 0 months. Other dependent variables for data analysis were: d) date of testing in month-long intervals--1) Sept. 8 to Oct. 3,

2) Oct. 6 to Oct. 31, 3) Nov. 3 to Nov. 26, 4) Dec. 1 to Dec. 12 (end of study, so last interval is only two weeks long); e) general area in which each child's school is located--1) Missoula metropolitan, 2) Missoula suburban, 3) Missoula rural, 4) Ravalli County, 5) Mineral County, 6) Sanders County, 7) Lake County (Appendix C). Data was not analyzed on a school-by-school basis because of the fact that not all schools have both morning and afternoon kindergartens.

The data was then coded (Appendix D), and analyzed, using a multivariate analysis of variance with the Statistical Package for the Social Sciences (SPSS 1980) on the DEC-system 20 computer at the University of Montana. The five-way ANOVA was to be performed twice, once using the actual numerical value of tympanometric-peak pressure in Pascals and a second time using the five defined peak pressure categories. The analysis was to be performed with multiple confidence levels, including .05, .01, .005, and .001, in an attempt to allow the reader a more flexible determination of the significance of any apparent differences shown in the data analysis.

CHAPTER III

RESULTS

The experimental hypothesis for the present study was that those kindergarten children who attend morning sessions and are tested in the morning have a higher tympanometric-peak pressure than children who attend and are tested in the afternoon. The analysis of the data was performed with computer assistance. The raw data used in the analysis of variance is contained in Appendix E. The results using the tympanometric-peak pressure in Pascals will be presented first, then the results using the five-category classification for the peak pressure will be summarized.

In order that each reader may individually decide the significance of these results, they are presented in terms of the highest level of confidence of the four selected levels, .05, .01, .005, and .001. In the following chapter, this writer will select one level of confidence for the purpose of discussion of results.

Because of limitations of the computer used to analyze the data, the analysis of variance using all five independent variables at once with the peak pressure (in either form) was not able to be computed. As a result, the analysis of the data was limited to the five possible ANOVAs, when combinations of four variables at a time were used (Table 3). In addition, very few results other than main effects of variables were reported by the computer, so the presence of higher-level interactions between variables is not known. This happened when the four variables included the two area and age or area and month, which did not contain the data necessary for computer analysis. That is, not all areas had subjects tested every month, nor did all areas have subjects of all age categories. This led to 0 values (which the computer terms "empty cells") and information about the existence of interactions was not reported in those cases. Consideration was given to combining data by collapsing categories so that 0 values and empty cells were filled, but this writer believed that the extensive recombination required would result in loss of information and be misleading as well as of little value to the study as a whole, and therefore chose not to proceed with this approach.

TABLE 3

Summary of Four-way ANOVAs
Using Five Variables

time, month, area, age category, sex

timeXmonthXareaXsex	by peak pressure
timeXmonthXareaXage category	in Pascals
timeXmonthXage categoryXsex	or
timeXareaXage categoryXsex	by peak pressure
monthXareaXage categoryXsex	category

A descriptive summary of the data is presented in Table 4. There was an AM:PM ratio of 1:1.54 and a male:female ratio of 1:1.08. The number of children tested each month shows a steady decline, as only the initial screening results were included in the study. Over 80% of the subjects were tested in the first two months of the study, September and October. The data by area shows a heavy concentration of subjects in the more urban areas of Missoula and the heavily populated Bitterroot Valley area. These areas (areas 1, 2, and 4) contained the vast majority of the subjects, over 70%. Approximately 80% of the subjects were contained within the two age categories 1 and 2, which included those children at least five years of age but not yet six years old.

TABLE 4

Summary of Experimental Variables

	n	% of total	AM n/PM n
TOTAL	1530		
BY TIME		% of total	
AM	928	61	
PM	602	39	
BY SEX			AM n/PM n
MALE	794	52	498/296
FEMALE	736	48	430/306
BY MONTH			
SEPT.	662	44	416/246
OCT.	575	37	344/231
NOV.	182	12	115/ 67
DEC.	111	7	53/ 58
BY AREA			
1. MSLA. metro.	596	39	349/247
2. MSLA. suburb.	199	13	121/ 78
3. MSLA. rural	49	3	31/ 18
4. RAVALLI CO.	304	20	179/125
5. MINERAL CO.	68	4	49/ 19

TABLE 4 (cont.)

BY AREA	n	%	AM /PM
6. SANDERS CO.	111	7	74/ 37
7. LAKE CO.	203	13	125/ 78
BY AGE CATEGORY			
1. 5 y 0 m to 5 y 5 m	597	39	375/222
2. 5 y 6 m to 5 y 11 m	684	45	397/287
3. 6 y 0 m to 6 y 5 m	219	14	136/ 83
4. 6 y 0 m to 6 y 11 m	30	2	20/ 10

Analysis Results (Peak Pressure in Pascals)

When using the independent variable of tympanometric-peak pressure, the actual numerical value in Pascals, the mean for the overall study sample was -827.15 Pa. Mean for the morning kindergarten children was -897.77 Pa and for the afternoon -718.29 Pa. The mean for males was -863.79 Pa and for females -787.83 Pa. The mean for each month showed a gradual increase of pressure from a low of -615.03 Pa in the first month (September) to a high of -1181.24 Pa in the third month (November), dropping slightly to a mean of -1067.38 Pa for the last month (December). Means by geographical area showed a wide variation ranging from a low of -665.55 Pa to -1262.09 Pa. The means for the different age categories varied within +/-50 Pa of -800 Pa (Table 5).

TABLE 5

Summary of Peak Pressure by Experimental Variables
(Peak Pressure in Pa)

	mean		
TOTAL	-827.15	(s.d.=1088.90)	
BY TIME			
AM	-897.77		
PM	-718.29		
BY SEX		AM mean	PM mean
MALE	-863.61	-950.33	-717.70
FEMALE	-787.83	-836.91	-718.86
BY MONTH			
SEPT.	-615.03	-681.63	-502.41
OCT.	-912.92	-1000.74	-782.14
NOV.	-1181.24	-1288.18	-997.67
DEC.	-1067.38	-1078.87	-1056.88

TABLE 5 (cont.)

BY AREA	mean	AM mean	PM mean
1. MSLA. metro.	-724.66	-753.07	-684.52
2. MSLA. suburb.	-949.99	-1074.42	-756.96
3. MSLA. rural	-665.55	-609.03	-762.89
4. RAVALLI CO.	-778.29	-983.70	-484.14
5. MINERAL CO.	-1262.09	-1366.20	-993.58
6. SANDERS CO.	-746.26	-792.09	-654.59
7. LAKE CO.	-1018.36	-958.29	-1114.64
BY AGE CATEGORY			
1. 5 y 0 m to 5 y 5 m	-850.60	-949.57	-683.41
2. 5 y 6 m to 5 y 11 m	-817.90	-872.34	-742.60
3. 6 y 0 m to 6 y 5 m	-790.79	-844.40	-702.95
4. 6 y 6 m to 6 y 11 m	-837.00	-794.50	-922.00

Five ANOVAs were performed with the dependent variable in the form of peak pressure in Pascals. Each ANOVA involved a different combination of four (of the total five) independent variables, (Table 6).Each variable was thus involved in four ANOVAs of the five. Information about the presence or absence of interactions was reported by the computer in only one case, the analysis not involving area. When examining the results of these

ANOVAs, patterns emerge which allow certain conclusions to be reached about the effects of individual variables in spite of the fact that the ANOVA involving all five at once could not be computed.

The effect of time was significant at the .001 level of confidence in all four ANOVAs that involved this variable. Month was also consistenly significant at the .001 level in four ANOVAs. The variables of sex and age were consistently not significant in any combination with other variables. Area was consistently significant at the .05 level of confidence when month was involved in the four-variable combination (three ANOVAs). In the ANOVA involving area but not month, area was significant at the .001 level of confidence. There were no interactions reported .

TABLE 6

ANOVA Summary Table
(Peak Pressure in Pa)

I.

Time (T) [morning versus afternoon], Month (M) [Sept. versus Oct...versus Dec.], Area (A) [Missoula versus...Ravalli...versus Lake], Sex (S) [male versus female]

SOURCE	SUM OF SQUARES	MEAN SQUARE	df	F ratio	PROB/HCL
T	13692126.000	13692126.000	1	12.116	.001/.001
M	48227043.000	16075681.000	3	14.226	.000/.001
A	16304699.000	2717449.800	6	2.405	0.026/.05
S	2582971.100	2582971.100	1	2.286	0.131/NS
ERROR	1665701400.000	1130055.200	1474		

II.

Time (T) [morning versus afternoon], Month (M) [Sept. versus Oct...versus Dec.], Area (A) [Missoula versus...Ravalli...versus Lake], Age Category (AC) [5.0 y to 5.5 y versus 5.6 y to 5.11...versus 6.6 y to 6.11 y]

SOURCE	SUM OF SQUARES	MEAN SQUARE	df	F ratio	PROB/HCL
T	14214368.000	14214368.000	1	12.553	.000/.001
M	49007075.000	16335692.000	3	14.426	.000/.001
A	16136835.000	2689472.600	6	2.375	0.027/.05
AC	1411655.500	470551.840	3	0.416	0.742/NS
ERROR	1666872700.000	1132386.300	1474		

TABLE 6 (cont.)

III.

Time (T) [morning versus afternoon], Month (M) [Sept. versus Oct...versus Dec.], Age Category (AC) [5.0 y to 5.5 y versus 5.6 y to 5.11...versus 6.6 y to 6.11 y], Sex (S) [male versus female]

SOURCE	SUM OF SQUARES	MEAN SQUARE	df	F ratio	PROB/HCL
T	13399811.000	13399811.000	1	11.596	.001/.001
M	37155982.000	22385627.000	3	19.372	.000/.001
AC	22254279.000	751426.320	3	0.650	0.583/NS
S	2199853.300	2199853.300	1	1.904	0.168/NS
T x M	1309869.400	436623.130	3	0.378	0.769/NS
T x S	1125530.800	1125530.800	1	0.974	0.324/NS
T x AC	1625680.100	541893.380	3	0.469	0.704/NS
M x S	3374256.500	1124752.200	3	0.973	0.404/NS
M x AC	11980212.000	1131134.700	9	1.152	0.322/NS
S x AC	2500740.400	833580.150	3	0.721	0.539/NS
ERROR	17302207600.000	1155575.400	1499		

TABLE 6 (cont.)

IV.

Time (T) [morning versus afternoon], Area (A) [Missoula versus...Ravalli...versus Lake], Age Category (AC) [5.0 y to 5.5 y versus 5.6 y to 5.11...versus 6.6 y to 6.11 y], Sex (S) [male versus female]

SOURCE	SUM OF SQUARES	MEAN SQUARE	df	F ratio	PROB/HCL
T	12708605.000	12708605.000	1	10.934	.001/.001
A	31830362.000	5305060.400	6	4.564	.000/.001
AC	355985.680	218661.890	3	0.188	0.905/NS
S	2607333.900	2607333.900	1	5.243	0.134/NS
ERROR	1713272400.000	1162328.600	1474		

V.

Month (M) [Sept. versus Oct...versus Dec.], Area (A) [Missoula versus...Ravalli...versus Lake], Age Category (AC) [5.0 y to 5.5 y versus 5.6 y to 5.11...versus 6.6 y to 6.11 y], Sex (S) [male versus female]

SOURCE	SUM OF SQUARES	MEAN SQUARE	df	F ratio	PROB/HCL
M	48189047.000	16063016.000	3	14.093	.000/.001
A	18821070.000	3136845.000	6	2.752	0.012/.05
AC	1601511.400	533837.150	3	0.468	0.704/NS
S	3295068.200	3295068.200	1	2.891	0.089/NS
ERROR	167779220000.000	1139804.300	1472		

NOTE: "HCL" is highest confidence level of four specified by this study, which were noted as .05, .01, .005, and .001. "NS" means not significant at any of these four levels.

Analysis Results (Peak Pressure Categories)

When using the independent variable of the five defined peak pressure categories, the mean for the overall study sample was 1.61, implying that the vast majority of the subjects were in either category 1 (normal) or category 2 (mild negative). The mean for the morning kindergarten children was 1.67, for the afternoon children 1.52. The means for males and females were 1.65 and 1.57, respectively. The means for each month show an increase from the first month to the third, 1.46 to 1.87, and a slight decrease in the mean for the fourth month to 1.83. Means by area show a wide variation from 1.45 to 1.90. Means for the four age categories vary within +/-.10 of 1.60 (Table 7).

TABLE 7

Summary of Peak Pressure by Experimental Variables
(Peak Pressure in Categories)

	mean		
TOTAL	1.61	((s.d.=0.90)	
BY TIME			
AM	1.67		
PM	1.52		
BY SEX		AM mean	PM mean
MALE	1.65	1.73	1.52
FEMALE	1.57	1.60	1.53
BY MONTH			
SEPT.	1.46	1.51	1.38
OCT.	1.67	1.75	1.55
NOV.	1.87	1.95	1.75
DEC.	1.83	1.85	1.81
BY AREA			
1. MSLA. metro.	1.51	1.52	1.49
2. MSLA. suburb.	1.68	1.79	1.51
3. MSLA. rural	1.45	1.39	1.56
4. RAVALLI CO.	1.63	1.81	1.38
5. MINERAL CO.	1.90	2.06	1.47

TABLE 7 (cont.)

BY AREA	mean	AM	PM
6. SANDERS CO.	1.58	1.59	1.54
7. LAKE CO.	1.79	1.74	1.86
BY AGE CATEGORY			
1. 5 y 0 m to 5 y 5 m	1.63	1.70	1.51
2. 5 y 6 m to 5 y 11 m	1.61	1.65	1.54
3. 6 y 0 m to 6 y 5 m	1.58	1.64	1.48
4. 6 y 6 m to 6 y 11 m	1.67	1.65	1.70

The ANOVAs which used the immittance measures in the form of peak pressure category had very similar results to those using the numerical value of peak pressure. These five ANOVAs were computed in the same way, each involving a combination of four of the five independent variables (Table 8). Again, patterns of effects emerged across the five analyses which led to conclusions about individual effects. Also, again only in the ANOVA that did not involve area was information about the presence or absence of interactions reported.

The effect of time was consistently significant at the .001 level of confidence in all four of the ANOVAs involving this variable. Month was also consistently significant at the .001 level of confidence in the four ANOVAs in which it was involved. Sex was not significant in three ANOVAs and significant at the .05 level when the variable time was not involved. Age was not significant in any of the four-variable combinations which were analyzed and included age as one of the four. Area showed inconsistent levels of confidence, being significant at the .001 level of confidence when the ANOVA did not involve month. In the three other ANOVAs that included area, the significance ranged from the .01 level of confidence (one case) to the .05 level of confidence(two cases).

TABLE 8

ANOVA Summary Table
(Peak Pressure Category)

I.

Time (T) [morning versus afternoon], Month (M) [Sept. versus Oct...versus Dec.], Area (A) [Missoula versus...Ravalli...versus Lake], Sex (S) [male versus female]

SOURCE	SUM OF SQUARES	MEAN SQUARE	df	F ratio	PROB/HCL
T	9.264	9.624	1	12.135	.001/.001
M	27.634	9.211	3	12.065	.000/.001
A	12.309	2.052	6	2.687	0.013/.05
S	2.636	2.636	1	3.453	0.063/NS
ERROR	1125.322	0.763	1474		

II.

Time (T) [morning versus afternoon], Month (M) [Sept. versus Oct...versus Dec.], Area (A) [Missoula versus...Ravalli...versus Lake], Age Category (AC) [5.0 y to 5.5 y versus 5.6 y to 5.11...versus 6.6 y to 6.11 y]

SOURCE	SUM OF SQUARES	MEAN SQUARE	df	F ratio	PROB/HCL
T	9.688	9.688	1	12.653	.000/.001
M	27.937	9.312	3	12.162	.000/.001
A	12.243	2.040	6	2.665	0.014/.05
AC	0.814	0.271	3	0.355	0.786/NS
ERROR	1125.698	0.773	1472		

TABLE 8 (cont.)

III.

Time (T) [morning versus afternoon], Month (M) [Sept. versus Oct...versus Dec.], Age Category (AC) [5.0 y to 5.5 y versus 5.6 y to 5.11...versus 6.6 y to 6.11 y], Sex (S) [male versus female]

SOURCE	SUM OF SQUARES	MEAN SQUARE	df	F ratio	PROB/HCL
T	8.958	8.958	1	11.425	.001/.001
M	36.705	2.336	3	15.604	.000/.001
AC	1.408	0.469	3	0.598	0.616/NS
S	2.336	2.336	1	2.979	0.085/NS
T x M	0.964	0.321	3	0.410	0.746/NS
T x S	1.507	1.507	1	1.922	0.166/NS
T x AC	0.510	0.171	3	0.217	0.885/NS
M x S	3.076	1.025	3	1.308	0.270/NS
M x AC	7.453	1.032	9	1.056	0.393/NS
S x AC	3.095	1.032	3	1.316	0.268/NS
ERROR	1175.334	0.784	1499		

TABLE 8 (cont.)

IV.

Time (T) [morning versus afternoon], Area (A) [Missoula versus...Ravalli...versus Lake], Age Category (AC) [5.0 y to 5.5 y versus 5.6 y to 5.11...versus 6.6 y to 6.11 y], Sex (S) [male versus female]

SOURCE	SUM OF SQUARES	MEAN SQUARE	df	F ratio	PROB/HCL
T	8.558	8.558	1	10.945	.001/.001
A	19.718	3.286	6	4.203	.000/.001
AC	0.459	0.153	3	0.196	0.899/NS
S	2.584	2.584	1	3.305	0.069/NS
ERROR	1152.498	0.782	1474		

V.

Month (M) [Sept. versus Oct...versus Dec.], Area (A) [Missoula versus...Ravalli...versus Lake], Age Category (AC) [5.0 y to 5.5 y versus 5.6 y to 5.11...versus 6.6 y to 6.11 y], Sex (S) [male versus female]

SOURCE	SUM OF SQUARES	MEAN SQUARE	df	F ratio	PROB/HCL
M	27.372	9.124	3	11.847	.000/.001
A	13.807	2.301	6	2.988	0.007/.01
AC	0.903	0.301	3	0.391	0.760/NS
S	3.149	3.149	1	4.088	0.043/.05
ERROR	1133.684	0.770	1472		

NOTE: "HCL" is highest confidence level of four specified by this study, which were noted as .05, .01, .005, and .001. "NS" means not significant at any of these four levels.

Because the effects of sex and age were generally not significant, regardless of the form of peak pressure used, a further ANOVA was computed (using peak pressure in Pascals) by time, month and area to further investigate these variables(Table 9). When all three variables were involved, time and month were both significant at the .001 level of confidence. Area was significant at the .01 level of confidence. Any interactions that might exist between these variables was not reported.

TABLE 9

ANOVA Summary Table
(Three-way ANOVA)

Time (T) [morning versus afternoon], Month (M) [Sept. versus Oct...versus Dec.], Area (A) [Missoula versus...Ravalli...versus Lake]

SOURCE	SUM OF SQUARES	MEAN SQUARE	df	F ratio	PROB/HCL
T	12878828.000	12878828.000	1	11.352	.001/.001
M	50135542.0000	16781147.000	3	14.731	.000/.001
A	16915996.000	2819332.600	6	2.485	0.021/.05
ERROR	1773174900.000	1134468.900	1563		

NOTE: "HCL" is highest confidence level of four specified by this study, which were noted as .05, .01, .005, and .001. "NS" means not significant at any of these four levels.

These three variables were then taken two at a time (in the three possible combinations) for one further ANOVA. The peak pressure by time, month ANOVA (Table 10)showed significant effects (at the .001 level of confidence) from both time and month with no interaction. The ANOVA involving peak pressure by month, area reported effects from month, significant at the .001 level of confidence , and area, significant at the .05 level of confidence. There was no interaction. The final ANOVA using peak pressure by time, area showed time significant (.005 level of confidence) and area significant as well (.001 level of confidence).There was an interaction between these two variables, significant at the .01 level.

TABLE 10
ANOVA Summary Table
(Two-way ANOVAs)

I.

Time (T) [morning versus afternoon], Month (M) [Sept. versus Oct...versus Dec.]

SOURCE	SUM OF SQUARES	MEAN SQUARE	df	F ratio	PROB/HCL
T	14871046.000	14871046.000	1	13.019	.000/.001
M	62054405.000	20684802.000	3	18.109	.000/.001
T x M	1337839.900	445946.640	3	0.390	0.760/NS
ERROR	1788753100.000	1142243.300	1566		

II.

Month (M) [Sept. versus Oct...versus Dec.], Area (A) [Missoula versus...Ravalli...versus Lake]

SOURCE	SUM OF SQUARES	MEAN SQUARE	df	F ratio	PROB/HCL
M	48705728.000	16235243.000	3	14.266	.000/.001
A	18908214.000	6151369.000	6	2.769	0.011/.05
M x A	16439643.000	1826627.000	9	1.605	0.108/NS
ERROR	1769614100.000	1138015.500	1555		

TABLE 10 (cont.)

III.

Time (T) [morning versus afternoon], Area (A) [Missoula versus...Ravalli...versus Lake]

SOURCE	SUM OF SQUARES	MEAN SQUARE	df	F ratio	PROB/HCL
T	11449014.000	11449014.000	1	9.908	.000/.005
A	28834859.000	4805809.800	6	4.159	.000/.001
T x A	20688466.000	3448077.600	6	2.984	0.007/.05
ERROR	1802622000.000	1156026.900	1560		

NOTE: "HCL" is highest confidence level of four specified by this study, which were noted as .05, .01, .005, and .001. "NS" means not significant at any of these four levels.

Summary of Analysis Results

Although the four-way ANOVAs used in the data analysis did not provide as definitive results as the five-way ANOVA would have, patterns within the five ANOVAs that were performed allowed certain conclusions to be drawn. Each variable was involved in four ANOVAs, in every possible four-way combination with three other variables. In most instances, the form of peak pressure (numerical versus categorical) did not affect the results to any great extent. Time of day of testing (morning versus afternoon) was consistently significant at the .001 level of confidence.

Month of testing was also consistently significant at the .001 level of confidence. Age on the day of testing (in six-month intervals)was not significant. Sex of the subject was not significant with any degree of consistency. The area in which the subjects lived was significant, at varying levels of confidence ranging from .05 to .001. Generally, area was significant at the more rigorous confidence levels if the variable month was not involved in the ANOVA, suggesting that a five-way ANOVA might show area to be significant only at a less rigorous level of confidence.

Only one interaction was discovered, using ANOVAs involving the three variables which had consistent significance: time, month, and area. The variables of area and time showed an interaction that was significant at the .01 level of confidence. The results of the data analysis suggest that the hypothesis of this study, that the time of day of testing (morning versus afternoon) makes a difference in the obtained tympanometric-peak pressure, is acceptable.

CHAPTER IV

DISCUSSION

The purpose of this study was to determine if morning kindergarten children have a higher tympanometric-peak pressure than afternoon kindergarten children. Since this is a exploratory study designed to examine a new variable in immittance testing, study, an error caused by too high of a confidence level (Type I error) was considered to be more desirable than failing to reject the null hypothesis because of a less rigorous confidence level (Type II error). The lack of previous research regarding the effects of time of day of testing on acoustic immittance measures was a factor in this writer's decision to use the .001 level for discussion purposes. However, as noted, the various levels of confidence are presented in the previous chapter for the express purpose of allowing each reader to decide what level of confidence he or she wishes to select for an individual interpretation of the data. Interestingly, only one of the five variables did not clearly fall into the significant or not significant groups.

The effects of the dependent variables will not be discussed in separate sections for the two forms of the acoustic immittance measures. The analysis of the data show the same significance for both the tympanometric-peak pressure in Pascals and the five-category classification. This similarity suggests that the categories are well chosen, as apparently no information was lost in categorizing the peak pressures, and eliminates the need to discuss them separately. The form of peak pressure in Pascals will be used to illustrate points in this discussion.

The most important finding is that the difference between the peak pressures obtained in the morning testing of kindergarten children versus those obtained in the afternoon testing was significant (at the .001 level of confidence). This finding is further enhanced by the fact that neither of the variables of sex or age were significant. The large sample size makes a favorable impact on the interpretation of these results as well.

This result clearly indicates that the time of day immittance measures are obtained from kindergarten-age children (on a morning versus afternoon comparison basis) has an effect on the location of the tympanometric-peak pressure. Unfortunately, the scope of this study did not allow for any investigation into the _causes_ for the difference. Any attempt to explain or suggest a reason for the significant difference must be done with little factual support. The question must be raised as to whether or not the difference can be traced to eustachian tube function, i.e., the ventilation of the middle ear. A child who attends kindergarten in the morning session has often just arisen from sleeping, when swallowing (and thus ventilation of the middle-ear space) occurs at a much slower rate. Children who attend afternoon kindergarten sessions have been awake and active for a longer period of time when immittance measures are obtained in the school screening compared with the time that the morning children have been when they are tested. This implies a longer period of time at a higher rate of swallowing for these afternoon kindergarten children, both while awake and while eating or drinking, perhaps leading to a possibility that the middle ear pressure is brought nearer to normal, i.e., 0 Pa peak pressure, by the ventilation provided by normal swallowing activity. This has the potential to change the peak pressure measurements obtained in the school screening. Another possible factor may be a difference in the general health of the children who attend at different times of the day. A child who goes to kindergarten in the morning may not sleep as long as one who goes in the afternoon. Children in morning kindergarten classes are outside at a much earlier time, which in the autumn months in west-central Montana means colder temperatures and damp air because of the tendency for fog to be present in the morning in the mountain valleys. There may be major differences in the selection of children who attend in the morning and those who attend in the afternoon, e.g., their socioeconomic status, but the study was unable to examine such factor(s). The results, regardless of the probable multiple causes, do point to and support the idea that tympanometric-peak pressure in children of kindergarten age is subject to transient changes which may occur within the span of only a few hours time.

The results allowed certain conclusions to be drawn; however, clinical implications from the results must approached cautiously. From the analysis of the data, the means for morning and afternoon kindergarten children (-897.77 and -718.19 Pa, respectively) showed a statistically significant difference. An additional question that this study hoped to answer was whether this difference was of <u>clinical</u> importance. Emphasis is placed on the fact that the two overall means did not fall on different sides of the pass/fail criteria. When examining the peak pressure categories(Table 11), the morning mean is 1.67, the afternoon 1.52. These both would indicate that the majority of the subjects in morning and afternoon were either category 1 (normal) or category 2 (mild). Looking further at the data, each category, whether morning or afternoon, shows a similar percentage of subjects, indicating that clinical management decisions, regardless of time tested, would be in the same proportions. For example, categories 3-5 (moderate, severe negative and flat) were in equal proportion in both morning and afternoon subjects, meaning that the percentage of the children failing the test and requiring either follow-up or medical referral would be the same regardless of what time they were tested. The difference in peak pressure that occurs because of the time of testing occurs in those subjects found in category 1 and 2--a result that is clinically unimportant. Both categories 1 and 2 would be considered passing in a screening program using the American Speech, Hearing, and Language Association criteria (Committee on Audiometric Evaluation 1979). In other words, the same percentage of morning kindergarten children passed the immittance testing as the afternoon children (categories 1 and 2); the same percentage of children in both morning and afternoon failed the immittance testing (categories 3 through 5) and thus required follow-up and/or medical referral. Although the difference between morning and afternoon kindergarten peak pressures was statistically significant, the conclusion must be made that kindergarten children in this study were not managed clinically any differently based on the time of day (morning versus afternoon) immittance measures were obtained.

TABLE 11

Summary of Peak Presure Categories by Time

CATEGORY	1	2	3	4	5
AM n	496	331	63	10	28
% OF AM	53	36	7	7	3
PM n	375	169	36	6	16
% OF PM	62	28	6	1	3
	AM PASS 827		AM FAIL 101		
	% PASS 89		% FAIL 11		
	PM PASS 544		PM FAIL 58		
	% PASS 90		% FAIL 10		

The month in which the immittance testing was performed was also consistently significant (at the .001 level of confidence). As the months progressed from September to December, there was a corresponding increase in the mean peak pressure, both overall and in morning versus afternoon. Studies previously cited (Eagles *et al.* 1963, Lildholdt 1980, Brooks 1971, Fiellau-Nikolajsen 1979) support a seasonal difference in tympanometric-peak pressure. Rather than present a month-by-month analysis of data, they simply contrasted seasons (typically summer and winter). The present study included the last four months of the year, during which the weather in west-central Montana ranges from summer-like weather in early September to winter weather in December.

While the area in which the subject lived when tested was not consistently significant, this writer believes that since area in certain ANOVAs was significant at the .001 level of confidence, a discussion of the data by area is in order. A closer examination of the data by area and time by area (Table 12) is helpful. As noted previously, there is a relatively wide range across areas, both in number of subjects tested in each area and in the mean tympanometric-peak pressure for each area, which is probably the reason for the significance of the area variable. The causes for this wide variation in mean peak pressures across the seven areas are possibly related to certain factors not examined in this study: different socioeconomic status, different levels of medical care and education, differences in racial background, different pollution sources and levels, etc.

TABLE 12

Summary of Peak Pressure by Area, Time

AREA	AM mean	AM n	PM mean	PM n	TOTAL mean	TOT. n
1	-753.07	349	-684.52	247	-724.66	596
2	-1074.42	121	-756.96	78	-949.99	199
3	-609.03	31	-762.89	18	-665.55	49
4	-983.70	179	-484.14	125	-778.29	304
5	-1366.20	49	-993.58	19	-1262.09	68
6	-762.09	74	-654.59	37	-746.26	111
7	-958.29	125	-1114.64	37	-1018.36	203

The interaction of the variables time and area was significant at the .01 level of confidence. Even though this is not the selected level of confidence for discussion, this interaction is the only reported interaction of the study and an inspection of the data shows trends that make it worthy of discussion. Two areas were probably of primary importance in the interaction of time and area, areas 3 (Missoula rural) and 7 (Lake County). These two areas may be the specific cause for the interaction of time and area, because both showed the reverse of the typical AM peak pressure greater than PM peak pressure, compared to the other five areas (Table 12). In these two areas, and only these two areas, the peak pressure for the afternoon children is greater than for the morning children. Since area 3 is the smallest of the seven areas, a decision was made to combine area 2 (Missoula suburban) and area 3 (Missoula rural) and determine whether this resulted in any change in the AM versus PM pattern of the area. Besides the small number of subjects from area 3, the division between areas 2 and 3 was considered to be the most arbitrary which gave credence to the rationale for combining of these two areas. Except for area 1 (Missoula metropolitan), all other areas were divided along county lines. The original division, then, may have been poorly chosen. In any case, the combination of area 2 and 3 resulted in interesting information (Table 13). With the two areas collapsed into one, the typical pattern of morning greater than afternoon mean peak pressure is seen.

TABLE 13

Summary of Peak Pressure by Time
(Areas 2 and 3 Combined)

TIME:	AM	-966.87
	n	152
	PM	-732.65
	n	96
TOTAL:		-875.02
	n	238

The interaction of time and area, then, apparently can be traced to area 7, Lake County. The number of subjects from this area cannot be suggested as a cause of the afternoon being greater than the morning mean peak pressure, as in the case of area 3. When the areas are ranked from largest to smallest, area 7 is fourth largest, i.e., the mode. The number in this area (mean n=203) is near the mean size for all seven areas (mean n=219).

Another possible factor contributing to the atypical results of area 7 is the month in which the immittance measures were obtained. As noted in the discussion of the effect of month of testing, the smallest difference between the morning and afternoon mean peak pressures was seen in December (the last month of the study). Approximately 33% of the subjects from area 7 were tested in December (69 of 203), the highest percentage of subjects tested in that month from any area. An examination of the mean peak pressure for the subjects in area 7 by month (Table 16) shows, when they can be compared, the pattern of afternoon greater than morning mean peak pressure. In all other areas (except area 3, which has been discussed) the data of time by month shows AM mean peak pressure greater than PM mean peak pressure.

TABLE 14
Area 7
Summary of Peak Pressure by Time, Month

MONTH	AM mean	AM n	PM mean	PM n	TOTAL mean	TOT. n
SEPT.	-682.14	22	0.00	0	-682.14	22
OCT.	-974.48	69	-1079.77	43	-1014.19	112
NOV.	0.00	0	0.00	0	0.00	0
DEC.	-1046.79	34	-1157.49	35	-1102.94	69

An examination of the data by school of this area and the time by school results (Table 15) reveals some interesting information but no simple explanation for the reversal in this area of the typical pattern of AM versus PM results. Of the six schools in area 7, two (numbers 5 and 6) have only morning kindergarten classes; both of these classes have mean peak pressures lower than the overall sample mean peak pressure as well as the mean peak pressure for morning subjects. One of the remaining four schools, number 3, has the typical morning greater than the afternoon mean peak pressure. Interestingly, this is the largest school in area 7. The school numbered 1 has morning and afternoon mean peak pressures that are virtually equal, although the PM is slightly greater than the AM mean peak pressure. Schools 2 and 4 show afternoon greater than the morning mean peak pressures, an obvious reversal from this study's general findings. The three schools that show this relation (numbers 1, 2, and 4) can be ranked first, second, and third in terms of highest mean peak pressure for this area. An analysis of the data in area 7 by time and school showed no significant effects (Table 16).

TABLE 15
Area 7
Summary of Peak Pressure by School,Time

SCHOOL	AM mean	AM n	PM mean	PM n	TOTAL mean	TOT. n
1	-1177.04	14	-1177.10	17	-1177.06	31
2	-955.55	20	-1139.00	18	-1042.45	38
3	-911.43	45	-875.77	22	-899.90	67
4	-1224.85	19	-1293.48	21	-1284.39	40
5	-682.14	22	0.00	0	-682.14	22
6	-353.00	5	0.00	0	-353.00	5

TABLE 16
Area 7
ANOVA Summary Table
(Two-way ANOVA of Time, School)

Time (T) [morning versus afternoon], School (Sch) [1 versus 2...versus 6]

SOURCE	SUM OF SQUARES	MEAN SQUARE	df	F ratio	PROB/HCL
T	46186.614	46186.614	1	0.025	0.874/NS
SCH	7965273.900	1593054.800	5	0.869	0.503/NS
TXSCH	295120.950	98373.651	3	0.050	0.984/NS
ERROR	357357330.000	1832601.700	195		

NOTE: "HCL" is highest confidence level of four specified by this study, which were noted as .05, .01, .005, and .001. "NS" means not significant at any of these four levels.

The discussion of area 7 results by individual school does not supply a explanation of why the results from this area are different from the other six areas, although the examination of this data gives interesting information. The question of what made this area different is still unanswered. Certain factors are easily ruled out; the location of area 7 in the Flathead and Jocko Valleys shares, for the most part, the climate and weather patterns of the other six areas. Further, the industrial and agricultural activities in area 7 are not substantially different from the rest of the study areas. One particular fact about area 7, however, sets it apart from the all other areas. Area 7 encompasses a major portion of the Flathead Indian Reservation, which is composed of native Americans who are members of the Salish-Kootenai tribes. As noted previously, race can have an effect on the incidence of middle-ear problems, and the native American population has shown a higher incidence of middle-ear disease/immittance screening failures than the white population (Lewis 1975, Roberts 1976, Johnson and Watrous 1978, Bess 1978, Wiet *et al.* 1980, Beery *et al.* 1980). The study of Beery *et al.* (1980) is of particular interest to the present study, for they reported

> This study indicated that the eustachian tube of the American Indian was functionally different from that of Caucasians previously studied and was characterized by comparatively abnormal, low passive resistance which may be considered to facilitate ventilatory function(p.28)... the abnormally low passive resistance observed in this population may facilitate the ventilatory function of the eustachian tube...(p. 32)

The conclusion that the native American population in west-central Montana may show this same "abnormal" function, causing different results than might be found with the white population, is a logical one. The fact that this study showed atypical results in the area with a native American population is consistent with Beery's findings.

A final possibility, of course, as an explanation for the results involving area 7 is that random chance has caused this reversal in the pattern of the study results, although this writer feels that the preponderance of native American children in this area was the probable cause of the reversal.

To summarize, the geographical area of testing had not only an effect on the results not only in the mean peak pressure, but also in the pattern of the relation between morning and afternoon means. In only one area was the mean peak pressure greater in the afternoon than the morning. This area, Lake County, has a significant native American population, which may have contributed to this difference. The possibility of a difference in the eustachian tube function because of race, as well as the potential for a higher-than-normal incidence of middle-ear problems in this population, may have caused a reversal of the AM greater than PM mean peak pressure seen typically in all other areas. The month of immittance testing was also shown to have a significant effect on the results. This effect is consistent with published research which suggests a seasonal difference in the tympanometric-peak pressure, especially in younger children. Most importantly, the time of day of testing was a significant variable in the results of immittance testing, regardless of sex or age (within a two-year range). The difference was statistically significant, but time of day of testing (morning versus afternoon) was seen not to make a difference in the clinical management of the subjects. While the significance of the effect of time of day on immittance testing cannot be discounted, the clinical implications do not demand any change in the present school hearing screening procedures for the kindergarten-age population.

CHAPTER V

SUMMARY AND CONCLUSIONS

The purpose of the present study was to determine if the time of day (morning versus afternoon) acoustic immittance was performed on kindergarten-age children affected the results of tympanometry, and whether any effects discovered had clinical importance. Based on informal observations from a school hearing screening program in west-central Montana, the hypothesis was that children who are tested in the morning have a higher tympanometric-peak pressure than children who are tested in the afternoon.

The subjects used in this study were 1530 kindergarten students in a five-county area of western Montana, all tested as part of a hearing conservation program with routine tympanometry as one part of the hearing screening procedure. The tympanometric-pressure was used in two forms: peak pressure in Pascals, and peak pressure in five discrete categories based on screening pass/fail criteria used in the program. Other factors that were considered about subjects were sex of the subject, age of the subject when tested (in six-month intervals), month of the testing, and geographical area in which the subject lived when tested.

Analysis of the data suggested that the time of day of testing, at least when compared on a morning versus afternoon basis, made a significant difference in the peak pressure obtained using tympanometry. The peak pressure of those children tested in the morning was indeed greater than that of children tested in the afternoon; however, the difference was clinically unimportant. The month in which the subject was tested also resulted in a significant difference in the testing, with a gradual increase in peak pressure noted from the study months of September to December, i.e., from late summer to fall to winter. This is consistent with published research which has suggested a seasonal variation in peak pressure. The area in which the child was living when tested made a significant difference not only in terms of the mean peak pressure from one area to the next, but also in the relation of morning to afternoon peak pressures. Age, in six-month intervals, and sex of the subject did not result in significant differences in the obtained peak pressure.

In this writer's opinion, the primary explanation for the findings of this study is related to the physiology of the eustachian tube, and concerns the ventilatory function of that structure and the possible differences in the amount of ventilation achieved at various times of the day.

This study was important because of the use of clinical data from an actual hearing conservation program operating in a public school system. From the beginning, the search for clinical implications has been as important, or more so, than the search for a statistically significant difference, in an attempt to obtain better hearing screening in the schools. The results clearly showed this conflict where some differences were found to be statistically significant but did not affect the clinical management of the children involved in this study. In addition, the present study has examined a factor which may affect the results obtained in acoustic immittance testing that has not been considered as an important variable in the past.

Conclusions

The following overall conclusions may be made from this study:

1. The time of day (morning versus afternoon) that tympanometry is performed has an effect on the results obtained with the kindergarten-age group, although any difference appears to be clinically unimportant with regard to audiologic follow-up and medical referral.

2. The month that tympanometry is performed has an effect on the obtained results; as the seasons change from late summer to winter (from September to December), there is an increase in the tympanometric-peak pressure, consistent with previously published research.

3. The geographical area in which the subject lives and is tested with tympanometry has an effect on the results that are obtained. This effect may be related to certain factors not investigated by the present study; e.g., socioeconomic status, medical care, educational level, etc. Within this study, however, racial background was possibly the most

important factor.

4. Age did not affect the results of tympanometry, possibly due to the small age range used (two years) or because the six-month age intervals used did not show the effect of age.

5. Sex of the subject did not have an effect on the tympanometry results in this one-time measurement study. Serial measurements might be expected to show some difference between the sexes.

Implications for Future Research

As this study is one that looks at a previously untested factor in acoustic immittance testing results, the information obtained and the positive outcome suggests a myriad of questions that need further investigation, including:

1. Would children of other ages, both younger and older, show the same differences in acoustic immittance results obtained at different times of the day, and would a difference in another age group be clinically important?

2. Would other routine acoustic immittance measures, used both in screening and in diagnostic applications, for example, middle-ear acoustic reflexes, show differing results when obtained at different times of the day?

3. What period of time is critical in making a difference in results obtained during the day?

4. Would differences caused by time of day of testing be consistent across all months and seasons?

5. What other factors, other than those examined by this study, are related to the difference in results obtained at various times of the day?

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APPENDIX A

DESCRIPTION OF THE PILOT STUDY

In order to determine if a significant difference existed between tympanometric-peak pressure in morning versus afternoon kindergarten children, a preliminary study of a small, randomly-selected portion of the total kindergarten sample was undertaken. For this study, the null hypothesis tested was: There is no difference between the peak pressure of kindergarten children tested in the morning and those tested in the afternoon.

Subjects for the pilot study were selected from the entire sample in the following manner: six schools, one from each area in the study,were chosen to be included, each having at least one morning and one afternoon kindergarten class. For those that had more than one morning and/or afternoon kindergarten, one class at each time was selected for inclusion in the pilot study from the different (up to four at one school) classes at each time. This selection was done by a person not familiar with the purpose of the study. From each of the twelve classes selected, rosters containing individual names (used in the screening program) were obtained. The second five names were recorded (#'s 6-10 on the rosters, not always in alphabetical order), and each individual child's screening record was recalled and the peak pressure was recorded for analysis. Absentees, those who could not be tested and/or failed otoscopic screening were not included. Because each ear was treated as an independent score, there were 120 possible scores, 20 from each school, 10 from each time of testing. Because of the criteria mentioned above, only 103 scores were recorded; 51 morning, 52 afternoon, ranging from 16 per school to 20 per school. Three further scores were not included because no peak pressure was obtained in the ear. Means and standard deviations were computed for each morning and afternoon kindergarten, by school and overall. t-test for a difference between two independent measures was then computed by school. A significant difference (at the .05 level of confidence) was found at only one of the six schools (Table a).

TABLE a

Summary of Pilot Study Results

SCH	am n	AM mean	AM s.d.	PM n	PM mean	PM s.d.	df	t	PROB
HW	10	-44.000	-71.056	10	-7.500	-23.717	18	1.540	NS
R	9	-49.890	-55.777	6	-20.830	-33.229	13	1.379	NS
MW	8	-93.750	-60.871	10	-5.000	-15.811	16	4.457	<.05
TF	8	-31.250	-45.806	8	-43.750	-62.321	14	0.451	NS
S	10	-115.000	-120.300	10	-95.000	-67.494	18	0.473	NS
F	8	-87.500	-70.710	10	-65.000	-63.683	16	0.752	NS
ALL	51	-68.630	-142.211	52	-44.230	-85.130			

Peak pressure measurements expressed in mm water. NOTE: "NS" means not significant at the .05 level of confidence.

Due to the inconclusive results of the initial study, the pilot study was extended to determine if a larger sample of all kindergarten children from one school would show support for the finding of such a difference. The school selected for a complete analysis had two important aspects; first, it was used in the initial investigation and none of the subjects were excluded (n=20), and second, it had the lowest resultant t value. Using the entire kindergarten (one morning and one afternoon class) from this school and using the same criteria, 72 scores were recorded. There were 36 scores recorded from each time of testing. The data was analyzed in the same way as the original analysis, and a significant difference was found at th .05 level of confidence (Table a1).

TABLE a1

Summary of Extended Study Results

SCH	am n	AM mean	AM s.d.	PM n	PM mean	PM s.d.	df	t	PROB
S	35	-137.14	-120.716	35	-81.250	-49.053	69	2.567	<.05

Peak pressure measurements expressed in mm water.

APPENDIX B

RESULTS OF STUDY OF INTER-EXAMINER RELIABILITY ACROSS SUBJECTS

	OBSERVER/MEASUREMENT						
EAR	A	B	C	D	E	mean	s.d.
1	0	0	0	+196	0	-39.2	-87.65
2	0	0	0	0	0	0	0
3	-580	-490	-490	-580	-490	-526.0	-49.30
4	-98	-245	-196	-196	-196	-186.2	-53.68
5	0	0	0	0	0	0	0
6	+196	0	+196	0	+196	+117.6	+107.35

All measurements taken consecutively on adult subjects using same impedance instrument; measurements of peak pressure expressed in Pascals.

<u>Pearson Product-moment Correlation (r)</u>

A versus B: 0.92; A versus C: 0.95; A versus D: 0.93; A versus E:.98; B versus C: 0.94; B versus D: 0.92; B versus E: 0.94; C versus D: 0.91; C versus E: 1.00; D versus E: 0.91.

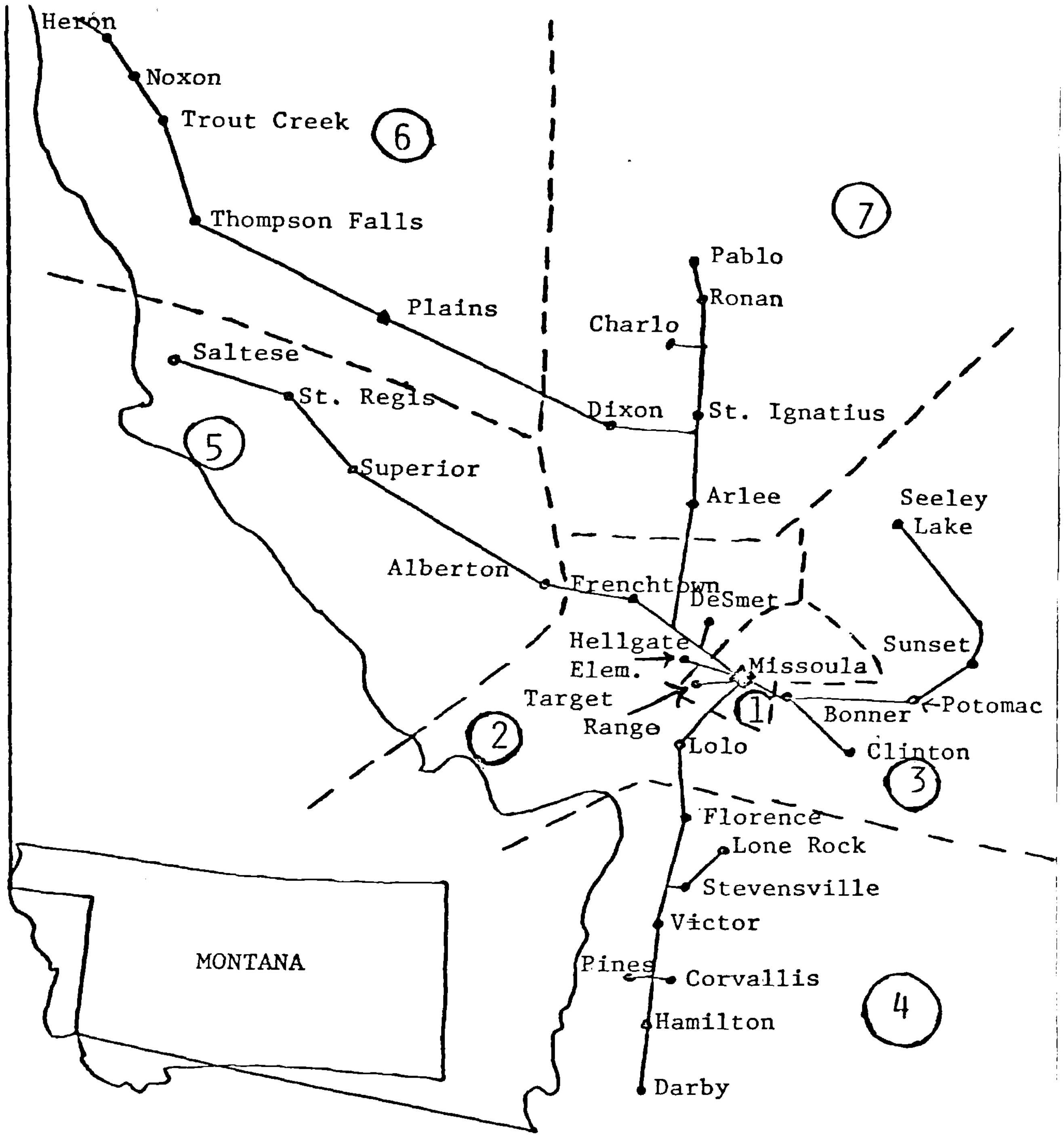
t-test for significance of r: When r=0.91 (lowest value of r, in C versus D correlation)), n=6:

t=4.3896 (df=4); t is significant at .05 level of confidence.

The significance of t indicates that with six observations, an r value of 0.91 would only be expected approximately 20% of the time, supporting the assertion that the inter-examiner reliability of the obtained measurements are adequate for this study.

APPENDIX C

MAP OF STUDY LOCATION SHOWING DIVISIONS OF AREAS 1-7



APPENDIX D

CODING OF DATA FOR DATA ANALYSIS

Definition of Spaces:

1--AREA WHERE TESTED
2-3--SCHOOL WHERE TESTED (for organization purposes only)
4--MONTH OF TESTING
5--TIME OF TESTING
6-7--INITIALS OF SUBJECT (for organization purposes only)
8--SEX OF SUBJECT
9--AGE OF SUBJECT WHEN TESTED
10--PEAK PRESSURE CATEGORY
11-15--PEAK PRESSURE IN PASCALS

Interpretation Of Codes:

AREA
1-Missoula metropolitan
2-Missoula suburban
3-Missoula rural
4-Ravalli County
5-Mineral County
6-Sanders County
7-Lake County

MONTH
1-Sept. (Sept.8 to Oct.3)
2-Oct. (Oct.6 to 31)
3-Nov. (Nov.3 to 26)
4-Dec. (Dec.1 to 12)

TIME
1-AM (morning kindergarten)
2-PM (afternoon kindergarten)

SEX
1-Male
2-Female

AGE (by six-month category)
1-5 y 0 m to 5 y 5 m
2-5 y 6 m to 5 y 11 m
3-6 y 0 m to 6 y 5 m

4-6 y 6 m to 6 y 11 m

PEAK PRESSURE CATEGORY
1-normal: +490 to -490 Pa
2-mild: +500 to +981, or -500 to -1962 Pa
3-moderate: >+991, or -1972 to -2943 Pa
4-severe negative: below -2953 Pa
5-flat: no peak pressure recorded at maximum pressure

PEAK PRESSURE IN PASCALS
+/- nnnn. (four-digit number preceded by positive/negative sign)

APPENDIX E

To interpret the data, see Appendix D.

AREA 1

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AREA 2

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20221jf132-0981.
20221jo132-0736.
20222kk212-0981.
20222de222-0981.
20222ls221-0000.
20222tw222-1471.
20222re232-0981.
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20222mc122-0736.
20222ch121-0490.
20222jm132-1962.
20331lm212-1962.
20331cc211-0490.
20331mo211-0000.
20331ph222-1373.
20331lg221-0000.
20331js221-0392.
20331lh232-0981.
20331jr111-0000.
20331cm112-1962.
20331kh112-1471.
20331mg122-1570.
20331jb122-1962.
20331tv122-0687.
20331el132-0981.
20332hb214-2943.
20332ss222-1962.
20332dm111-0196.
20332jh122-0981.
20332js122-1766.
20421bn213-2943.
20421am211-0490.
20421le221-0000.
20421ma231-0000.
20421fr111-0000.
20421dd121-0490.
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20122sm111-0000.
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20221mf221-0000.
20221kp221-0490.
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20221mg132-1226.
20221ap132-1226.
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20222sd232-1962.
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20222jb122-0981.
20222mc121-0490.
20222tw122-0981.
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20331an211-0392.
20331jh213-2943.
20331aw215-4905.
20331lj221-0000.
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20331ht222-1962.
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20331cs111-0000.
20331mw112-0981.
20331jz111-0000.
20331bh122-1766.
20331jh122-0785.
20331ss131-0000.
20331jl131-0294.
20332mm212-1177.
20332md231-0392.
20332gc123-2551.
20332th122-1177.
20332bg121-0490.
20421ec211-0000.
20421jw211-0000.
20421ma221-0000.
20421th114-3924.
20421ls111-0000.
20421jm122-1471.
20122gg112-0736.
20122hf131-0490.
20221ld211-0490.
20221mh222-0981.
20221nr221-0245.
20221jy222-0981.
20221dt111-0490.
20221jl123-2942.
20221pn133-2452.
20221ss132-0736.
20222sp212-0981.
20222co221-0000.
20222as221+0245.
20222li231-0245.
20222rh112-1471.
20222ac121-0000.
20222jf121-0000.
20222ng131-0490.
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20331jh213-2354.
20331en212-1471.
20331rs211-0000.
20331ky223-2452.
20331kk223-2354.
20331sm232-0580.
20331tm112-1373.
20331gs112-1962.
20331js111-0000.
20331ma123-2452.
20331an124-3532.
20331bl125-4905.
20331bt132-1962.
20331ns133-2747.
20332tm221-0000.
20332bb113-2158.
20332de121-0000.
20332jr121+0392.
20332es131-0490.
20421cd211-0000.
20421rr212-0981.
20421jk222-0981.
20421eb111-0000.
20421gj122-1471.
20421cs142-1471.

20422tb211-0000.
20422hb211-0000.
20422jd221-0490.
20422mb111-0490.
20422ts111-0000.
20422cw111-0000.
20422mt121-0000.
20511jl212-1471.
20511tn221-0000.
20511bh121-0245.
20511mw122-1962.

20422gr211-0000.
20422je211-0000.
20422ls223-2943.
20422jp111-0490.
20422md111-0000.
20422lr111-0000.
20422cc121-0000.
20511nn211-0490.
20511lw112-0981.
20511jm121-0000.

20422af211-0490.
20422eo221-0490.
20422th113-2452.
20422tr112-0981.
20422je111-0000.
20422jd121-0490.
20422je121-0000.
20511jk221-0490.
20511sb122-0736.
20511pm121-0000.

AREA 3

30111as211-0490.
30111sh211-0000.
30111ld211-0000.
30111kb231-0245.
30111th111-0490.
30112aj211-0000.
30112ts221-0000.
30112ah111-0000.
30112ea121-0490.
30211jm211-0490.
30211ll221-0245.
30211rb121-0490.
30211bh121-0245.
30211jn122-0736.
30211jw132-1962.
30312ac222-0981.
30421jg212-1471.

30111br212-0981.
30111lo211-0000.
30111ma222-0981.
30111mk112-0981.
30111dc132-1226.
30112ah222-1226.
30112lh225-4905.
30112mt121-0245.
30112rm121-0000.
30211tc221-0000.
30211jb111-0490.
30211bb121-0000.
30211bm122-0981.
30211dr121-0490.
30312jl211-0490.
30312sf222-1962.

30111ky211-0000.
30111js211-0000.
30111al221-0000.
30111nh112-0981.
30112ao212-0981.
30112ag222-0981.
30112ah111-0490.
30112ds122-0981.
30112gh121-0000.
30211mh222-1962.
30211ws111-0000.
30211cg121-0000.
30211am123-2943.
30211dr131-0000.
30312lb211-0000.
30312iv121-0000.

AREA 4

40111hb212-1962.
40111kl212-1471.
40111bc113-2943.
40111mr112-1668.
40111mb121-0000.
40111sr122-0981.
40112aw211-0000.
40112ek223-2699.
40112ss221-0000.
40112kz221-0000.

40111kc212-0785.
40111mn211-0000.
40111jh112-1668.
40111es111-0490.
40111tk121-0000.
40111js122+0785.
40112pb221-0000.
40112tl221-0000.
40112js221-0490.
40112jh111-0490.

40111ah211-0000.
40111sa222-0981.
40111sp115-4905.
40111mb121-0000.
40111bm122-0785.
40112ld211-0490.
40112se221-0490.
40112ss221-0490.
40112lw221-0490.
40112cm111-0490.

40112th122-0981.
40112ms121-0000.
40211rs212-1570.
40211bf222-1373.
40211jd112-0785.
40211mt111-0392.
40211jk123-2354.
40311hm214-3532.
40311sb222-0785.
40311lh231-0196.
40311gf112-0580.
40311km112-0981.
40311ts111-0392.
40311cb121-0196.
40311dg121-0392.
40311dm122-0785.
40311jn132-0580.
40312cf213-2452.
40312sc221-0294.
40312kp221-0000.
40312hr221-0490.
40312an231-0000.
40312ca111-0000.
40312dh111-0000.
40312al111-0000.
40312cb121-0392.
40312jf122-1177.
40312mt121-0000.
40411db215-4905.
40411tw211-0000.
40411dc212-0785.
40411jm222-1962.
40411jc221-0000.
40411jw221-0000.
40411db232-1962.
40411am111-0000.
40411mc125-4905.
40411dw121-0490.
40411jw121-0392.
40411dk121-0000.
40411jp131-0000.
40412js211-0392.
40412sg222-0580.
40412lb221-0000.
40112jh121-0000.
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40211kr111-0196.
40211tb131-0490.
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40311ag221-0392.
40311dp233-2943.
40311pg112-1766.
40311cm112-0580.
40311dt111-0392.
40311wf122-0981.
40311jk121-0000.
40311sr122-0580.
40311js132-0785.
40312mp211-0000.
40312jl221-0000.
40312jp221-0000.
40312cw221-0000.
40312js231-0000.
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40312ch112-1962.
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40312wk122-1373.
40312rw121-0000.
40411cs211-0490.
40411rs212-0785.
40411am211-0000.
40411ks221-0000.
40411mb223-2452.
40411aw221-0000.
40411cc111-0490.
40411cm111-0000.
40411ds122-0981.
40411br121-0196.
40411bw121-0785.
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40411ch131-0000.
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40412kh221-0000.
40412jb221+0196.
40112dp122-1471.
40211dh212-1177.
40211cf222-1177.
40211ls221+0196.
40211ps112-0785.
40211ba122-0580.
40211jg141+0196.
40311rs212-1766.
40311kl221-0196.
40311lb111-0196.
40311ml112-0785.
40311js112-0580.
40311mb121-0392.
40311cg122-0785.
40311bj121-0000.
40311bs121-0196.
40311jd132-0785.
40312jt215-4905.
40312dl222-0580.
40312dr221-0000.
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40312mt231-0000.
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40312jj112-0785.
40312jp111-0490.
40312bd121-0000.
40312ts121-0196.
40312tm131-0000.
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40411jo211-0000.
40411nb221-0000.
40411dt221-0000.
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40411ll112-1177.
40411dt111-0000.
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40411jl122-1962.
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40411mn133-2158.
40412ss211-0000.
40412bs211-0000.
40412tm221+0196.
40412tc221-0000.

40412aw221-0000.
40412bl111-0000.
40412ml122-1177.
40412jk122-0736.
40412kz121-0000.
40412cw131-0000.
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40531dp211-0490.
40531aw231-0392.
40531ss112-1177.
40531tm112-1177.
40531bc122-1962.
40531dd121-0000.
40531tl121-0000.
40531nw133-2452.
40531dg143-2158.
40532ys213-2747.
40532nc221-0000.
40532kj221-0000.
40532bv231-0392.
40532tb111-0392.
40532mg131-0392.
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40621sj222-0580.
40621ma112-0981.
40621jf122-0785.
40622ma212-0981.
40622ch222-0687.
40622ma231-0000.
40622rj112-0785.
40622ck132-0785.
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40711js221-0000.
40711tb113-2551.
40711zp115-4905.
40711rc121-0490.
40712np211+0196.
40712wf223-2158.
40712bh112-0981.
40712sp111-0196.
40712gb121-0000.
40712bz141-0000.
40811ah221-0000.

40412jg111-0000.
40412bt111-0000.
40412jm122-1471.
40412cm121-0000.
40412ea132-0580.
40412dw131-0000.
40531sp212-1962.
40531bh222-0580.
40531kb231-0000.
40531sc115-4905.
40531jw112-0981.
40531jl121-0000.
40531rf121-0000.
40531jr121-0000.
40531lz132-0981.
40531pm141-0392.
40532sb222-0785.
40532md222-0580.
40532iv223-2158.
40532jm231-0392.
40532cm111-0000.
40532cv141-0000.
40621ck213-2158.
40621aj222-0981.
40621dr231-0196.
40621ag113-2747.
40621pw122-1373.
40622ut211-0490.
40622tm221+0098.
40622rj242-0687.
40622dw111-0000.
40622jn131-0000.
40711cs215-4905.
40711sm232-1177.
40711wh112-0687.
40711ce121-0196.
40711mt135-4905.
40712mr212-1766.
40712lj221-0000.
40712rl112-0785.
40712ep111-0000.
40712bh124-3728.
40811gl211-0000.
40811jb223-2452.

40412jv111+0196.
40412mb121-0000.
40412kt121-0392.
40412jn121-0000.
40412be131-0000.
40531sb212-1962.
40531cp212-0580.
40531ts221-0000.
40531bm111+0294.
40531bg111-0000.
40531ca122-0981.
40531mw124-3433.
40531ah121-0392.
40531ms125-4905.
40531am131-0000.
40531bs141-0000.
40532ab222-1373.
40532tg221-0000.
40532al222-1766.
40532mb231-0000.
40532ac131-0000.
40621aa211-0196.
40621ms211-0196.
40621jr222-1570.
40621js232-0687.
40621bs111-0000.
40621sj122-0981.
40622dw211-0000.
40622no221-0000.
40622dj112-0785.
40622do111+0196.
40711kc212-0580.
40711js215-4905.
40711na112-0981.
40711rr115-4905.
40711pn121-0490.
40712jb213-2354.
40712cr212-0580.
40712cs221-0000.
40712do111-0000.
40712at111+0196.
40712tk132-0785.
40811as212-0981.
40811ab232-0981.

408111f112-1471.	40811af112-0981.	40811eh112-0580.
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40811ah122-0785.	40811pl121-0196.	40811ww122-1766.
40811jw121-0000.		

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50111dc212-0981.	50111jc211-0000.	50111ke211-0490.
50111tm212-0981.	50111mm211-0000.	50111at212-0981.
50111rd221-0490.	501111h221-0245.	50111tn221-0000.
50111ar222-1471.	50111st222-0981.	50111ag122-0981.
50111dm121-0000.	50111sd132-1962.	50221ej212-1225.
50221cv215-4905.	50221tm212-1962.	50221ah222-0981.
50221ch222-1471.	50221ab231-0490.	50221cc231-0490.
50221ke232-1471.	50221jf231-0000.	50221at112-0981.
50221dh124-3433.	50221jm124-4414.	50221tm122-0981.
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50222rp222-0981.	50222kv221-0490.	50222kw221-0245.
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50222am221-0490.	50222dl221-0245.	50222wk241-0490.
50222gm111-0245.	502221b111-0490.	50222jg112-1471.
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50321cw213-2452.	50321sm213-2943.	50321mk222-0981.
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50321cp122-0981.	50321rm122-0981.	50321bs125-4905.
50321af131-0000.	50321es131-0000.	50442mg211-0490.
50442sg121-0490.	50442ng143-2943.	

AREA 6

60111ab211-0490.	60111ah211-0490.	60111sm221-0000.
60111jv111-0000.	60111dm121-0000.	60211ak212-0981.
60211jk211-0000.	60211sm211-0000.	60211ks212-0981.
60211wt211-0000.	60211co221-0000.	60211ms222-0981.
60211ds223-2452.	60211jl111-0000.	60211jn111-0000.
60211js112-1471.	60211nv111-0000.	60211jg122-0981.
60211jm122-0981.	60211sr121-0000.	60211rs122-1962.
60311ah212-0981.	60311dk213-2943.	60311gn211-0981.
60311ff221-0000.	60311tl221-0000.	60311jp111-0490.
60311ap112-0981.	60311ss111-0490.	60311eg123-2452.

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60411jk122-0736.
60411rb131-0000.
60412ph211-0000.
60412js221-0000.
60412kh221-0000.
60412tg111-0490.
60412dc122-0981.
60541jd212-0785.
60541dh211-0000.
60541km221-0000.
60541rr231-0392.
60541rr111+0490.
60541dr121-0000.
60541sm142-0981.
60542mc222-1962.
60542mv223-2158.
60542lc232-1962.
60542mp231-0196.
60542ca123-2747.
60542tw121-0000.
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60411bm211-0000.
60411ak221-0490.
60411jw221-0000.
60411em113-2452.
60411bn112-0981.
60411jd122-0981.
60411ro121-0490.
60412cb211-0000.
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60412jw222-0981.
60412kk231-0000.
60412jw111-0000.
60412cs121-0000.
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60541as224-3433.
60541rc111-0490.
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60541cb131+0196.
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60542wg231-0000.
60542th231-0000.
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60542cd124-3335.
60311bm122-0981.
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60411jr111-0000.
60411sg111-0000.
60411dh125-4905.
60411ds121-0000.
60412rb211-0490.
60412dh221-0000.
60412hg221-0000.
60412jh242-1471.
60412jg112-0981.
60412jb132-0981.
60541ah212-0981.
60541di222-1962.
60541jd232-1962.
60541nc111-0490.
60541kc122-0891.
60541ms131+0392.
60542kb212-0785.
60542ck222-0580.
60542lc231-0196.
60542bh232-0785.
60542sm242-0981.
60542mw121-0000.
60542rr131-0000.

AREA 7

70141eb213-2158.
70141kd223-2158.
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70141bf121-0294.
70141cw122-1766.
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70142nc231-0000.
70142cs111-0196.
70142cm121-1177.
70142js122-0981.
70142sw131-0294.
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70241dm225-4905.
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70141ae222-1766.
70141ts115-4905.
70141jg122-1962.
70141db131-0000.
70142mw211-0000.
70142ad235-4905.
70142tf121-0000.
70142cm124-3139.
70142tt121-0392.
70241mp213-2943.
70241kc222-0580.
70241rs223-2354.
70141sw211-0000.
70141rh221-0294.
70141ca121-0000.
70141sr121-0000.
70142jm211-0294.
70142ab233-2943.
70142cf231-0392.
70142rf121-0000.
70142pp121-0392.
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70241ml222-0981.

70241jh221-0392.
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70242da131-0000.
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70321jm211-0000.
70321qc211-0392.
70321ks221-0392.
70321cm221-0000.
70321se231-0000.
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70321rw112-1766.
70321cb112-0981.
70321cw115-4905.
70321js122-1177.
70321jd121-0000.
70321js121-0000.
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70321jw133-2158.
70322mg212-0981.
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70322mp232-0580.
70322jh115-4905.
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70322mc121-0000.
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70421sg232-1668.
70421ad111-0000.
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70422df213-2354.
70422ap212-1962.
70422sh225-4905.
70422ts221-0000.
70422dm231-0196.
70241ss222-0981.
70241ab231-0000.
70241ks122-1766.
70241bm141-0196.
70242bm222-0981.
70242cm221-0000.
70241bg111-0000.
70242jc125-4905.
70242es122-0785.
70242ac131-0490.
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70321cs211-0098.
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70321ds221-0392.
70321mp222-0981.
70321cb231-0000.
70321tc112-0785.
70321sj111-0000.
70321jg112-1570.
70321md121-0196.
70321bs122-1373.
70321kg121-0245.
70321cs124-3335.
70321bc132-1177.
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70322mk221-0392.
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70322dc112-0785.
70322sh111-0000.
70322co111-0196.
70322ah122-0736.
70421je214-3335.
70421as211-0196.
70421ci231-0000.
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70421jc121-0196.
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70422cs211-0000.
70422kl222-0580.
70422st222-1570.
70422sp115-4905.
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70241ks111-0000.
70241sd131-0000.
70242sg212-0981.
70242hr222-1962.
70242tm232-0981.
70242ml111+0392.
70242jk121-0392.
70242gl122-1373.
70242ch141-0196.
70321kp211-0392.
70321nw212-1766.
70321hp221-0000.
70321mb221-0000.
70321mr222-0785.
70321gb111-0196.
70321mm115-4905.
70321wb111-0392.
70321rj115-4905.
70321cj121-0196.
70321rs122-0785.
70321rr121-0000.
70321kc131-0392.
70321rn132-0981.
70321sd141-0000.
70322tb221-0000.
70322al222-0981.
70322ah231-0000.
70322mp111-0000.
70322dl113-2747.
70322jw111-0490.
70322ss122-1962.
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